DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **CSG 15**

Research and Development

Final Project Report

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Executive summary (maximum 2 sides A4)

This report addresses two major areas of work: one is the monitoring and assessment of pelagic trawl and gillnet fisheries to determine cetacean bycatch levels, while the other addresses experimental approaches to understanding and mitigating cetacean bycatch.

Bycatch monitoring of fisheries has focused on pelagic trawlers, especially in the southwest bass pair trawl fishery. Observers spent 333 days at sea monitoring 421 fishing operations; 299 of these operations were in the bass pair trawl fishery where 87 common dolphins were recorded caught in bass pair trawls. No cetaceans were observed in 146 days at sea and 122 hauls in other pelagic trawl fisheries.

We have broken down fishery landings statistics to gain a better understanding of the distribution of fishing effort by pelagic trawlers. The six major species targeted are mackerel, herring, pilchard, sprat, horse mackerel and bass. When considered in terms of expected number of operations, there is approximately equal fishing effort in three zones, the North Sea, the Celtic Sea/Channel/Irish Sea and the Atlantic, with on average around 1600-1800 operations per year in each zone over all fisheries. We have observed around 7.5% of the number of hauls that would be expected in a recent average year.

We can express our observations of zero bycatch in terms of the likely maximum bycatch rate in each fishery and area. In so doing we can highlight those fisheries and areas where our observations still leave room for the greatest possible uncertainty. Principally these are the mackerel fishery, and the sprat fishery in the Channel and Celtic Sea.

In the bass fishery total bycatches are of the order of 90 dolphins per year, based on an average of 32% observer coverage in the last 3 years. This represents less than 0.1% of the most recent estimate of common dolphin abundance in the area, and also compares with an estimate of 200 dolphins per year in the hake gillnet fishery. We are pursuing methods to minimise the bycatch in the bass fishery.

We have made observations during 252 days at sea in gillnet and tangle net fisheries. 43 of these have been in the southwest, and the rest in Yorkshire, covering experimental trials of different gillnet materials. In the southwest we have observed 194 hauls in tangle net and gill net fisheries without observing any porpoise bycatch. This is not inconsistent with expected rates of bycatch based on what we have observed elsewhere in the UK.

Gill and entangling net fisheries in the southwest are dominated by tangle net fisheries for crayfish, monkfish, rays and turbot, which peak during the summer months, and gillnet fisheries for hake, Pollack and cod, which peak in the early months of the year. Annual porpoise bycatch totals for gillnet and tangle net fisheries in this area cannot be determined at present, but even with conservative assumptions about likely catch rates these are likely to be in the region of 500 porpoises per year, which compares with an interim target of 200 porpoises.

Recent trends in gillnet effort have been downwards in most parts of the UK. Revised porpoise bycatch estimates for the North Sea and the West of Scotland are of around 440 and 50 animals per year respectively, though these estimates are based on sampling done mainly during 1996-2000.

There has also been a slight decline in recent years in pelagic trawl fishing effort, but no inferences on cetacean bycatch can be drawn form this.

We have run a series of three gillnet trials using a chartered gillnet vessel in Yorkshire. Analysis of observer records suggested that multi-monofilament nets have a much higher porpoise bycatch rate than monofilament nylon nets. When we tested this in a controlled trail, we found no difference in the bycatch rates between the two net types, and presume that the observed correlation is not indicative of any causal link between the type of twine and bycatch rate.

Our second trial involved comparing porpoise and seal bycatch rates in standard skate monofilament nets (267 mm mesh size and 0.6mm twine diameter) with a thin twined net of 0.4 mm monofilament. Here we found an order of magnitude difference in the bycatch rate of both seals and porpoises, with fewer animals, but more large holes, recorded in the thin twined nets. We speculate that thinner twines may be easier to escape or fall from.

Our third trial involved barium sulphate filled polyamide (nylon) nets in a comparison with standard nylon monofilament nets. These are intended to have a higher acoustic reflectivity and therefore to enable porpoises to detect them acoustically. The barium sulphate nets had slightly smaller mesh size and a thicker twine diameter (0.67mm). We found that the barium sulphate nets had a significantly higher bycatch rate of porpoises and a higher bycatch rate of seals and again speculate that this may be because of the twine diameter and strength.

We have begun some trials of net strength in collaboration with the University of Dundee. These confirm the relative strength of the barium sulphate nets and the relative weakness of the 0.4 mm monofilament nets. Further work on this will follow.

Our work on using porpoise click trains to develop a means of localising animals has been severely constrained in agreement with DEFRA in order to release resources for the enlarged gear trials described above. The limited amount of work that we have done in this area has so far simply served to highlight many of the technical problems inherent in such an approach to studying porpoise movements.

Work done under this project in relation to the bass pair trawl fishery has been extended through two additional contracts with DEFRA that have funded equipment purchase and hire, and vessel time to develop an exclusion grid to prevent dolphin bycatch in pelagic trawls. The results of this work are appended, as staff time was covered under the present contract.

Much of the work achieved under this project has been in terms of direct input into the UK's small cetacean bycatch response strategy and other DEFRA conservation initiatives, as well as to international forums such as the International Council for the Exploration of the Sea and the EC's Scientific Technical and Economic Committee on Fisheries (STECF).

Scientific report (maximum 20 sides A4)

Introduction

Work under this contract has been focussed on two main areas. The first involves estimating cetacean bycatch rates in pelagic trawl and gillnet fisheries, while the second involves examining how and why porpoises become caught in gillnets.

The report is therefore divided into two main sections to address these two issues. A third section summarises the ways in which this work has been used during the project to provide advice to government on bycatch and on bycatch mitigation.

1. Cetacean bycatch rate estimation

1.1 Pelagic trawl fisheries.

1.1.1 Observations

Our original objective was to try to monitor around 300 days at sea on pelagic trawlers in the UK over three years, recording any cetacean bycatch to estimate bycatch rates. We chose 300 days at sea because the UK pelagic fleet typically makes around 6,000 days at sea and 300 days therefore represents around 5% of one year's fishing effort. Levels of coverage of 5-10% of annual effort are thought to be generally sufficient to obtain an initial approximation of the level of bycatch in a fishery that has not previously been monitored (SEC 2002).

Observers were initially placed on mackerel and herring vessels fishing from Peterhead and Fraserburgh, and also from Plymouth. Aberdeen University also began an EC funded monitoring programme of pelagic trawl fisheries shortly after the present study began and in order to minimise conflicts in obtaining berths, it was agreed with them that they would focus mainly on Shetland vessels, and that SMRU would focus mainly on the Peterhead and Fraserburgh boats.

No attempt was made to randomise observer placement. This is not currently practicable as there is no requirement, obligation nor real incentive for skippers to take observers and we therefore rely upon their goodwill to take observers. We obtained much assistance in the placement of observers from the Scottish Pelagic Fishermen's Association, and with few exceptions have found that skippers are happy to take observers on board.

Observers record details of the fishing operation on each trip, including any factors that we believe may help in estimating total fleet bycatch or determining how or why cetaceans become caught in fishing operations.

Table 1. Observations by fishery

Main Target	Days at Sea	SumOfNoHauls	Cetaceans observed
Anchovy	4	4	0
Bass	187	299	87
Blue Whiting	8	4	0
Herring	35	46	0
Mackerel	73	34	0
Pilchard	10	9	0
Smelt	2	6	0
Sprats	10	10	0
Whiting[1]	4	9	0
TOTALS	333	421	87

Following some adverse publicity of the bass fishery in the Southwest in 2000, we were for a short while denied access to bass or mackerel boats fishing in the southwest. However skippers among the boats pair trawling for bass and their Association approached us in December of 2000 to initiate a collaborative approach to addressing the issue of cetacean bycatch in that fishery. Since then we have diverted a great deal of time and project resources from the present project to addressing this one fishery, which, though very small, has become the focus of public concerns over cetacean bycatch. We have through two additional contracts with DEFRA (MF0733 "Bycatch reduction in pelagic trawl fisheries" and MF0735 "Further development of a dolphin exclusion device") attempted

[1] Pair trawlers working within 6-mile of the Devon/Cornwall coast also taking bass. Gear is demersal trawl.

to improve our understanding of how dolphins get caught in this fishery and to develop means of preventing dolphin bycatch. This is considered in further detail below.

Overall we achieved 333 days at sea and more than half of this (187 days at sea) was in the bass fishery. We therefore spent 146 days at sea in other pelagic trawl fisheries without observing any cetacean bycatch. A summary of our observations by fishery and by port of departure are given below in Tables 1 and 2.

Table 2. Observations by Port of Departure

Departure Port	Days At Sea	Hauls observed	Cetaceans recorded
Lerwick	14	11	0
Peterhead	19	15	0
Fraserburgh	55	36	0
Oban	4	4	0
Southend	16	24	0
Torquay	2	1	0
Plymouth	211	312	80
Looe	7	13	0
Brixham	5	5	7
TOTALS	333	421	87

The categorisation of fisheries has been based on the primary target for each trip undertaken and requires some further explanation. The major UK pelagic fisheries in terms of value of landed catch are mackerel, herring, sprat, horse-mackerel, pilchards and bass. Other species are only taken occasionally, in small tonnages and or with just a few days at sea. Anchovies for example have only been taken during an average of 19 days at sea per year over the past five years. In some cases the target species is also not well defined at the trip level, with more than one species forming the bulk of the catch in individual hauls during the trip. We may therefore have observed a haul that was composed primarily of blue whiting in a trip that would otherwise have been recorded as a mackerel trip.

1.1.2 Pelagic trawl fishing effort by the UK fleet

The number of hauls that we have observed needs to be put in context with regard to the amount of fishing effort by the UK fleet. To this end we have used fishery landings records provided by CEFAS and by SEERAD for all UK vessels landing into UK or foreign ports. Trip records include the weight of fish landed by species from each ICES rectangle visited in the trip, the gear type used and the number of days at sea. Some trips also have the number of hauls given, but this is not consistent and in many cases this information is missing.

We have generated standardised records for the UK fleet as a whole, and allocated fishing effort on a pro-rata basis among all the ICES rectangles from which fish were recorded taken for each individual trip. Thus a trip of 6 days landing 60 tonnes of fish from three ICES rectangles in equal proportions is allocated 2 days per rectangle. The allocation is weighted by the total fish landings taken from each rectangle, so that for a trip in which 90% of landings by weight come from one ICES rectangle, 90% of fishing effort is also allocated to that ICES rectangle.

For each trip we also determine the greatest value species that was landed and assume that this is the target species for that trip. This is the only way to determine the fishery within the landings database, as there is no obligation to declare the target species in a landings declaration or logbook form. Sometimes a high value bycatch species may obscure the intended target species, but this is unusual.

Once we have allocated each trip to a notional fishery and allocated fishing effort among the ICES rectangles fished during that trip, we can allocate fishing effort, in terms of days at sea, to each fishery and ICES rectangle or Division. Our observations however are made with respect to hauls, and a more useful and accurate representation of fishing effort would therefore be to determine the number of hauls within each fishery on a regional basis. To this end we have selected all the records from the landings data for which the number of tows was declared and used these records to estimate the number of tows per day in each fishery within each of three major areas. These areas were chosen partly for convenience and partly to represent different cetacean 'zones' and consist of the North Sea (ICES Division IV), the 'Atlantic' Divisions V,VI,VIIbck, and VIII) and the 'Celtic Seas' (VIIadefghj). We would expect the major pelagic dolphins present in these areas to be the white-beaked dolphin, the Atlantic white-sided dolphin and the Common dolphin respectively, though clearly all three species may occur on all three areas.

Tables 3 shows the average number of days at sea per year in each of 11 pelagic trawl fisheries over a five year period. A 12th category is denoted by 'other' which may represent minor fisheries or trips where some bycatch species had the highest value.

In Table 4 we have calculated the average number of hauls per day for each of these fisheries, where there were sufficient data in the landings records to do so. We assume that there is no bias in the reporting of the number of tows made during a trip, so that those trips for which 'number of tows' are given are representative of all trips in that fishery/area. We also include the mean number of tows per day at sea for our own observations for each fishery by way of comparison. There are no major differences between these two sets of figures supporting our belief that the landings records may not be unduly biased.

Table 3: Five year average annual fishing effort by UK pelagic trawlers by Region

Fishery	Average annual total days at sea 1998-2002	REGION		
		Atlantic	Celtic Sea	North Sea
Anchovy	19	15	4	0
Bass	191	0	191	0
Blue Whiting	9	9	0	0
Capelin	4	0	0	0
Herring	2072	762	167	1092
Horse Mackerel	230	46	170	14
Mackerel	3012	1609	554	848
Other	339	134	131	67
Pilchard	148	0	142	6
Sea Bream	2	0	2	0
Sprat	830	370	275	185
Tuna	15	13	2	0
TOTALS	6867	2958	1638	2212

Table 4: Mean number of tows or hauls per day by fishery and region from the landings data, and by fishery from SMRU observations.

Fishery	Overall mean tows per day	REGION			SMRU Observations
		Atlantic	Celtic Seas	North Sea	
Anchovy	2		2		1
Bass	1.62		1.62		1.59
Blue whiting					0.5
Capelin					
Herring	0.81	0.55	0.94	0.8101	1.31
Horse Mackerel	0.67	0.74	0.61	1.5097	
Mackerel	0.40	0.39	0.41	0.3725	0.46
Pilchard	0.88		0.88	0.754	0.9
Sea Bream	1.4		1.4		
Sprat	1.61	1.5	1.48	1.8204	1
Tuna	0.56	0.56			
Other	1.79	0.81	2.08	1.8446	

From Tables 3 and 4 we can now estimate the number of tows made in each fishery and region during an 'average year' over the past five years. These figures are shown in Table 5.

There were neither observations nor records in the landings database of the number of tows per day by the small number of boats taking capelin. The significance in terms of the number of fishing operations of the herring, sprat and mackerel fisheries now becomes more clear. Furthermore the differences in terms of fishing effort between the three areas that was seen in Table 3 has been substantially reduced. .

Table 5: Estimates of expected annual total fishing effort in terms of number of tows or hauls per year by fishery and region.

FISHERY	OVERALL	Atlantic	Celtic Sea	North Sea
Anchovy	38	30	8	0
Bass	310	0	310	0
Blue Whiting	18	18	0	0
Capelin	?			
Herring	1687	420	157	885
Horse Mackerel	154	34	104	21
Mackerel	1199	625	225	316
Pilchard	130	0	126	5
Sea Bream	3	0	3	0
Sprat	1336	555	405	337
Tuna	8	7	0	0
Other	605	108	272	124
TOTALS	5488	1797	1610	1688

1.1.3 Observations in context

Our observations, made over three years, can be compared with the expected number of fishing operations in an "average year" for each fishery and region. This has been done in Table 6 where our observations are expressed as a percentage of the number of expected fishing operations.

Table 6: Cumulative observer coverage expressed as a percentage of the expected number of operations in an 'average year' during 1998-2002

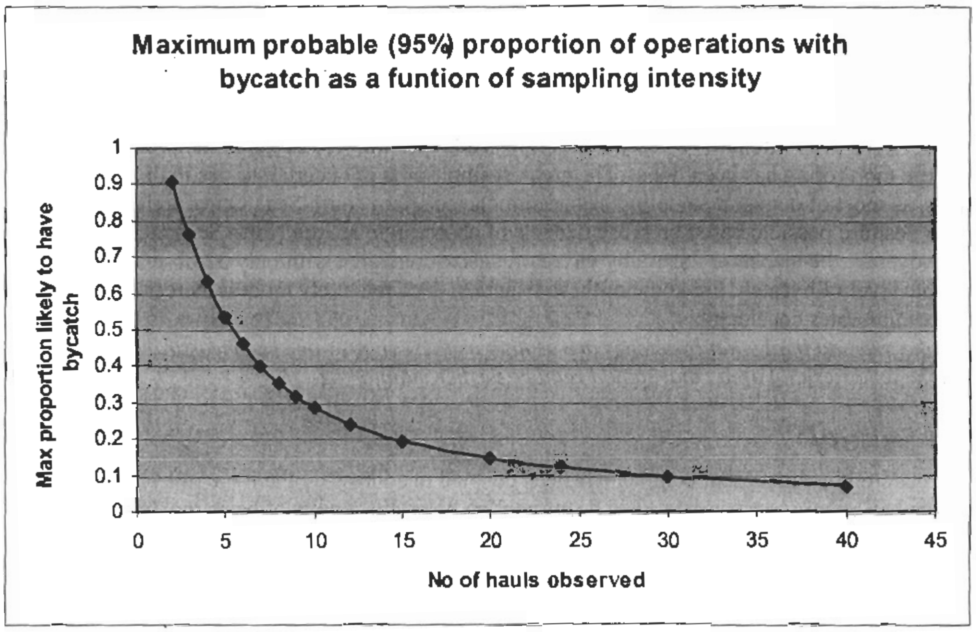
FISHERY	Overall % coverage	Atlantic	Celtic Sea	North Sea
Anchovy	10.4%	0.0%	52.6%	
Bass	95.3%		95.3%	
Blue Whiting	22.2%	22.2%		
Capelin	-			
Herring	2.8%	1.0%	1.3%	4.6%
Horse Mackerel	0.0%	0.0%	0.0%	0.0%
Mackerel	2.7%	3.0%	4.0%	1.3%
Pilchard	5.4%		5.6%	0.0%
Sea Bream	0.0%		0.0%	
Sprat	1.4%	0.7%	0.2%	4.2%
Tuna	0.0%	0.0%		
Other	1.5%	0.0%	3.3%	0.0%
TOTALS	**7.6%**	**1.7%**	**20.3%**	**3.5%**

Despite having observed on fewer than 5% of the average number of days at sea (328 of a putative 6867, or 4.7%), when expressed in terms of fishing operations we have observed over 7.5% of the expected number of hauls per year. The coverage, however, is far from even, and the focus on bass fishing in the Channel has meant that for many other fisheries levels of coverage are lower than ideal.

The ideal levels of observer coverage in any fishery can be determined statistically if one can specify a level of bycatch that it is important to be sure is not being exceeded. This subject was explored in detail under an additional contract with DEFRA (*Monitoring levels required in European Fisheries to assess cetacean bycatch with particular reference to UK fisheries, Northridge and Thomas 2003*). The report is appended to this report as an Annex (Annex 1), as SMRU staff time for this work was covered under the present contract.

The work to determine appropriate monitoring levels also provides a means of specifying the likely maximum bycatch rate in fisheries where no bycatch has been observed. For most of the pelagic trawl fisheries that we have observed we have not observed any cetacean bycatches. This does not mean that there are *no* cetacean bycatches in these fisheries, but in most cases it may mean that the probability of any particular operation in that fishery resulting in any cetacean bycatch may be low. But the observations of zero bycatch can be used to determine what the likely maximum bycatch rate is. If we assume that fishing operations with and without cetacean bycatch can be modelled as a binomial process with an underlying fixed probability p of observing a bycatch event, the probability p can be determined fairly simply from the binomial distribution. The details are given in Annex 1, but Figure 1 shows this graphically.

Figure 1: Likely maximum proportion of 'bycatch positive' operations as a function of the number of 'non-bycatch' operations observed.[2]



For any given number of observed hauls with no bycatch one can specify the maximum likely proportion of all hauls that have no bycatch. Thus if five hauls are observed without any bycatch, and bycatch is assumed to have a binomial distribution – that is bycatch events are randomly distributed within the fishery and with respect to the observations – one can be 95% sure that no more than 53% of all hauls will have any cetacean bycatch. In Table 7 we have tabulated the likely maximum proportion of hauls that we could expect to have any cetacean bycatch based on the number of zero bycatch observations made in each of six fisheries in three regions. Where no observations have been made the likely maximum is 1.0 by definition, and although common sense dictates that this is unlikely where there is no empirical evidence to the contrary the maximum possible rate is 1.

Table 7. Likely maximum proportion of hauls in which bycatch could be expected.

Fishery	Overall	Atlantic	Celtic Seas	North Sea
Anchovies	0.634	1.000	0.634	1.000
Blue whiting	0.634	0.634	1.000	1.000
Herring	0.069	0.634	0.905	0.077
Horse mackerel	1.000	1.000	1.000	1.000
Mackerel	0.321	0.156	0.321	0.634
Pilchards	0.404	1.000	0.404	1.000
Sprats	0.156	0.634	0.995	0.211

Using the figures from Table 5, one can also deduce the likely maximum *number* of hauls with cetacean bycatch for each of the fisheries listed in Table 7. These are given in Table 8 below.

Table 8. Likely maximum number of hauls in which bycatch could be expected.

Fishery	Overall	Atlantic	Celtic Seas	North Sea
Anchovy	24	30	5	0
Blue Whiting	11	11	0	0
Herring	116	266	142	68
Horse mackerel	154	34	104	21
Mackerel	***385***	***98***	***72***	***200***
Pilchard	53	0	51	5
Sprat	209	352	403	71

[2] Note that the method used to make these calculations is described in Annex 1, but is an approximation

This table is useful not as an indicator of likely cetacean bycatch rates, but as an indicator of where the most important uncertainty currently lies. It should be borne in mind that these numbers are simply what we expect to be the maximum possible number of hauls that could take cetaceans in any of the fisheries given the number of hauls that we have observed without bycatch. The actual numbers of cetaceans taken under these extreme assumptions would be greater, as the mean or expected group size in a trawl tow with bycatch is between 4 and 5 animals in both the bass fishery and the Irish tuna trawl fishery. It would be possible to calculate the upper confidence limits for bycatch estimates as described in Annex 1, but we have not done this here as it would serve little purpose other than to produce alarming bycatch numbers.

Another feature of Table 8 is that the overall column shows quite different results from the sum of the regional columns. This is because sampling has not been proportional to effort across regions and the stratified samples can produce disproportionately high numbers where very little monitoring has been done. The greatest single area of uncertainty lies in the sprat fisheries of the Celtic Seas and Atlantic areas, as most of our sprat sampling has been in the southern North Sea. Other highlighted fisheries where 200 or more bycatch hauls per year are possible based on present levels of observation are the North Sea mackerel fishery and the Atlantic herring fishery. Taken overall, the mackerel fishery by virtue of its size compared with only 32 observed hauls remains the fishery with the greatest possible level of bycatch. For some of these fisheries, even relatively modest increases in observer effort could reduce these likely maximum rates considerably.
These figures must not be taken to imply that bycatches are as high as these figures or even measurable in any of these fisheries. They simply highlight the fisheries and areas that should require further monitoring.

1.1.4. The bass fishery

Much of the staff time covered by the present contract has been devoted to addressing the issue of bycatch in the bass pelagic pair-trawl fishery. More than half of all observer days have been spent on board the 4 pairs of boats that have been involved in this fishery in recent years, and considerable effort has been placed into trying to develop means of minimising or eliminating dolphin bycatch in this fishery. Additional costs to this end, in terms of equipment and more recently vessel hire have been covered by two additional contracts with DEFRA (MF0733 & MF0735). The reports of these contracts are appended to this report as Annex 2 and Annex 3. An overview of the bass fishery and the observations over the past three years was also presented as a working paper at the 2003 meeting of the Scientific Committee of the International Whaling Commission and this paper is appended as Annex 4. Here we provide only a brief further summary of this work.

The pelagic pair trawl fishery for bass in Division VIIe and VIId is a small fishery operated by a few Scottish boats in the winter months, but over the past five years or more, mainly in late February and March. The summed total effort between 1998 and 2002 is presented in Figure 2, below, demonstrating the importance of the month of March for this fishery. This is because the vessels involved in this fishery are not able to fish inside the 12 mile zone, while bass do not move that far offshore in any significant numbers until late February during their annual spawning in the mid Channel. Prior to this they are predominantly distributed in more coastal waters and are targeted by inshore vessels using gillnets and trawls, though most of these are demersal trawls with an important catch of several other species including whiting.

Skippers of the Scottish boats are of the opinion that the bycatch of dolphins has been worsening in recent years, despite a decline in fishing effort (see Figure 3) and with little change in their area of operation. Observers have recorded a minimum of 87 short-beaked common dolphins taken in 299 observed hauls; skippers have provided further records when observers have not been present. Highest bycatch rates have been recorded in late February and March, at the peak of the fishery. The reasons for this are unknown, but common dolphin stomachs have not been recorded with bass, and the bass that spawn in the Channel are all over 37cm in length, whereas dolphin stomachs typically contain mackerel, sardines and scads with lengths typically around 20cm. Bass are also very fast swimming, have sharp spiny dorsal fins, and do not school in very dense schools. In short it seems unlikely that the bass influence the distribution of dolphins directly.

Among the 299 hauls observed only 20 (6.7%) were 'bycatch hauls', and the number of animals counted per haul ranged from 1 to a maximum of 10 with a mean of 4.35 dolphins. Average school size for short-beaked common dolphins around the UK has been reported as 14 animals (Reid et al 2003), which suggests that either school sizes in the Channel in March are smaller than average or that only a part of a school is typically caught in these operations with the rest escaping.

Figure 2: Monthly pattern of effort in the pelagic pair trawl fishery for bass.

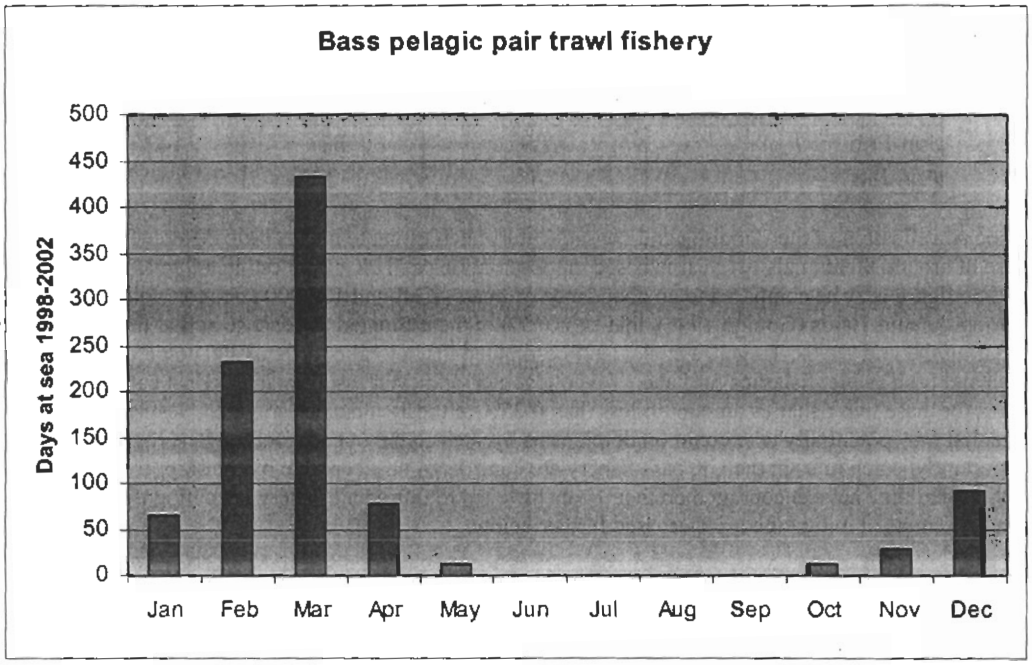
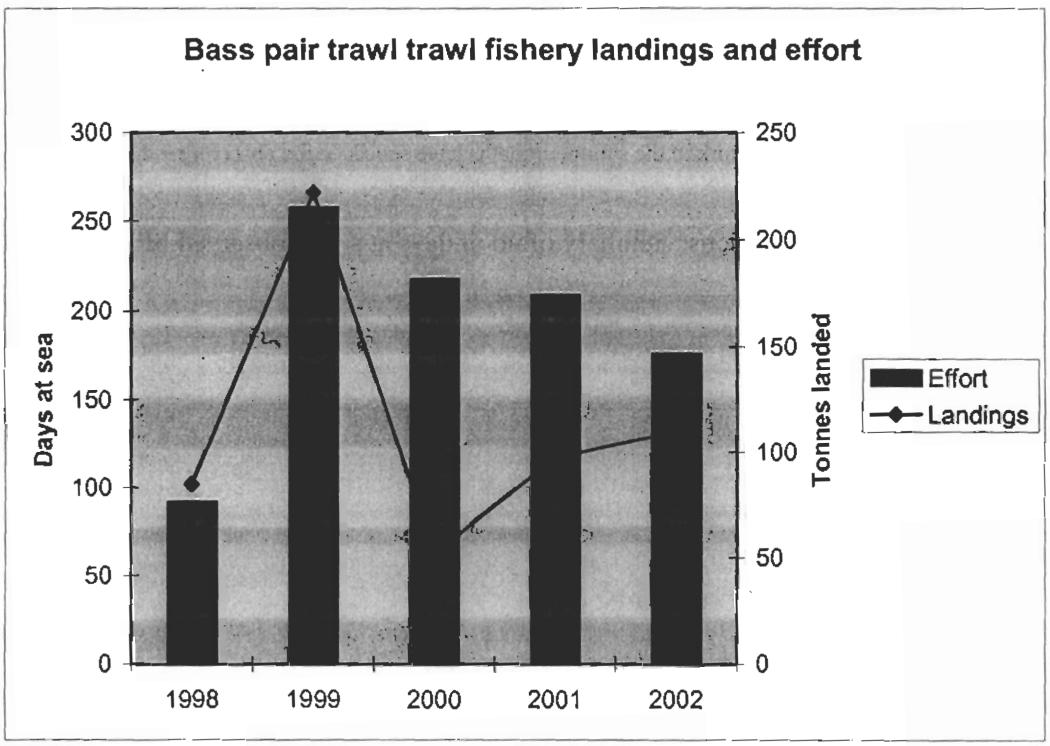


Figure 3: Recent trends (1998-2002) in bass pair trawl fishing effort.



Bycatch rates, as mentioned above, peak during late February and March. Thus only 1 animal has been observed in 136 hauls observed in the offshore fishery between April and January, while 86 have been observed taken in 159 hauls in February and March. (An additional four hauls were observed in December an inshore trawl fishery with no bycatch observation). The observed seasonal difference in catch rates suggests that it may be sensible to stratify any estimates of total fleet bycatch by the two major periods, February and March, and the rest of the year. Estimates of total bycatch are given in Table 8 below, together with 95% confidence limits, for an 'average year' during the three-year sampling period 2000-2002. An average year assumes 190 days at sea and 310 hauls per year, with 54% of hauls in February and March and 46% during the rest of the year.

Table 8: estimates of total mortalities of common dolphins in the UK bass pair trawl fishery for an 'average' year – based on mean effort and observed bycatch rates 200-2002

	Point estimate	Lower	Upper
Unstratified estimate:		95 % Confidence Limit	
All months	91	53	147
Stratified estimates:			
Jan-Feb	89	52	143
Apr-Jan	1	0	4

In this case, post-hoc stratification of the sampling and consequent bycatch estimate makes little difference in the estimates of total bycatch. The figure of around 90 animals per year is based on observations of 32% of the estimated total fishing effort over the three years 2000-2002. The figure may be compared to an abundance estimate of around 120,000 common dolphins in the Celtic Sea and adjacent waters during the mid 1990s (Goujon 1996), that is 0.075% of the estimated abundance at that time. In another study of cetacean bycatch during the mid 1990s, Tregenza et al. (1997) estimated that a total of around 200 common dolphins per year are taken in the English and Irish gillnet fisheries for hake. Taken together, and even assuming the gillnet catches continue at the same rate, total mortalities for these two fisheries amount to less than 0.25% of the abundance estimate. Nevertheless there are many other fisheries in the area that may potentially take common dolphins as bycatch so the overall total may be higher than these figures suggest. More importantly, catch rates in the UK bass fishery are considered unacceptable by the skippers of the boats involved, while the observations that they have encouraged on their boats have led to this small fishery becoming a cause celebre with the local and national media. Attempts at mitigation are discussed further below.

1.2 Gillnet and Tangle Net Fisheries.

1.2.1 Observations

Our objective with respect to gillnet and tangle net fisheries was to target 300 days at sea, and to focus most closely on the south and west. The shifting focus of the present project, coupled with consequent logistical constraints, has meant that while we have almost met our target for observer effort (252 days), this has mainly been diverted to other fisheries, both the pelagic trawl fisheries and experimental studies of porpoise bycatch in North Sea gillnet fisheries that were extended during the project (see below).

Working with two observers for the first half of the project and just one for the second half, pelagic trawl observations during the winter months and experimental gillnet trial work in the summer months have squeezed the observer resources available for work with netters in the southwest.

Table 9: Gillnet observations: summary of no of days at sea & observed hauls by port.

Port of landing	Days at sea	Number of observed hauls
SOUTHWEST		
Helford	3	9
Mevagissey	12	48
Newlyn	4	15
Padstow	2	8
Plymouth	22	114
TOTAL Southwest	43	194
YORKSHIRE		
Bridlington	209	1080

Observations have been spread, thinly, among most of the important fishery types in the southwest, though we have avoided the offshore hake fishery that has already been sampled extensively in two previous observer-based studies. Observations by fishery are given in Table 10.

Table 10: observations by fishery type in the Southwest:

Target	Number of hauls	Number of porpoises	Likely maximum bycatch rate (porpoises/N hauls) N=
Tangle nets			
Rays/crustacea	34	0	11
Mixed species	14	0	5
Monk	13	0	4
Gill nets			
Pollack/cod	117	0	32
Sole	4	0	2
Bass	12	0	4

No cetacean bycatches were observed during the present restricted study, though given the low number of hauls observed overall (194) this is not surprising, and remains consistent with observations made elsewhere in the country where porpoise bycatch rates range from 1 in 22 hauls (skate/turbot North Sea) to 1 in 217 hauls (inshore cod, North Sea). Following Figure 1 we can give approximate likely maximum bycatch rates based on these observations (Table 10, last column).

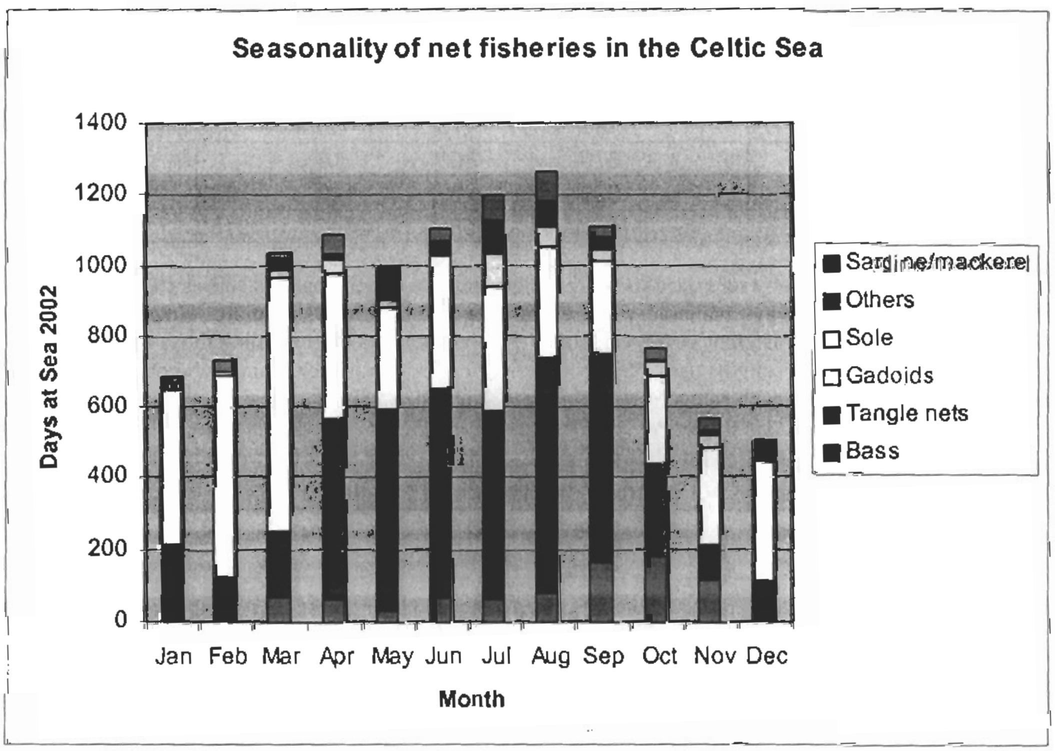
1.2.2. Gillnet and Tangle net fishing effort by the UK fleet

1.2.2.1 The Southwest

As described previously for pelagic trawl fisheries, we have collated landings data for the entire UK fleet and have allocated fishing effort by gill and entangling net fisheries to ICES rectangles, and also allocated each trip a 'target' based on the landed species with greatest aggregate value.

Gillnet fisheries in the Southwest as elsewhere show some seasonality on this basis, with most of the fisheries targeting species caught with tangle nets concentrated in the summer months, and highest effort for cod, pollack and hake in the early months of the year. The seasonal patterns are shown in Figure 4, derived from the landings statistics. Trips where gadoids accounted for greatest aggregate value accounted for 41% of all days at sea, while trips deemed to be tangle net trips accounted for 39%.

Figure 4: Gill and tangle net fisheries by month. "Gadoids" include all trips where cod pollack or hake were the most valuable landings while "Tangle nets" includes all trips where crustaceans, rays, turbot or monkfish were the most valuable landings.



Clearly this characterisation of fisheries operating in the Celtic Sea is a simplification, concealing many differences in gear characteristics, specific targets, vessel types and areas of operation. Landings records list more than 90 species of fish taken by gill and entangling nets in the Celtic Sea. Fishing effort can also be examined by vessel length class as well as by assumed target species (most valuable item in landings records). In Table 11 we have tabulated the number of days at sea by vessel length category and by one of 21 notional target groups.

Tregenza et al. (1997) studied porpoise bycatch in the fishery for hake, pollack and other gadoids by vessels of 15m and over in the Celtic Sea in 1993-4. Porpoise bycatch rates at that time were around 0.046 animals per haul, with an average of 2.9 hauls per day, resulting in a bycatch rate per day of 0.134. Estimates at the time of that study were of around 700 porpoises per year being taken by that sector. Effort in that sector has subsequently fallen and if porpoise bycatch per unit effort rates were still the same today, and if the amount of netting per haul and the number of hauls per day has remained constant since then, we might expect current bycatch levels in this fishery to be around 240 porpoises (from 1788 days at sea). This part of the overall UK gill and entangling net fisheries of the Celtic Sea (highlighted above) currently accounts for only around one sixth (16%) of the days at sea. It does not follow, however that overall porpoise bycatch might therefore be six times that of the hake/pollack fishery, as the amounts of netting used in smaller size classes of vessel is considerably shorter than those used in the offshore hake fishery.

Table 11: Fisheries in the Celtic Sea: fishing effort by vessel length category and target species group for 2002

Target	Total	0-10m	10-15m	15-20m	20m+
Bass	935	603	40	215	77
Cephalopod	17	15	2		0
Cod	516	435	53	9	19
Cray	200	16	176	8	0
Crust	1573	1377	170	26	0
Dog	9	4	3		2
Gadoid	2688	824	1017	599	248
Hake	1342	3	398	701	240
Herring	86	86			0
Mackerel	196	193	3		0
Monk	1457	1032	401	16	8
Mullet	153	128	25		0
Other	213	159	12	37	5
Other flatfish	24	4	8	7	5
Plaice	5	5			0
Sardine	182	177	5		0
Shark	13	4	9		0
Shell	4	4			0
Skate	141	75	66		0
Sole	379	360	19		0
Turbot	929	95	140	538	156
TOTALS	*11062*	*5599*	*2547*	*2156*	*760*

Some idea of net lengths can be obtained by reference to the landings database which contains entries for the amounts of netting hauled per day. These figures are not always available, and are evidently also not always accurate. However, some idea of the likely differences in net lengths being used by different vessel categories may be obtained by examining those data that are available. In Table 12 we have tabulated the mean net lengths used per day (in kms) for vessels of each length category in the Celtic and North Seas. We have taken the mean value for each category only for those trips where the data were recorded.

Table 12: Average net length used per day by length class of boat (km)

Length class:	10-	10-12	12-15	15-20	20+
Celtic Sea	3.74	8.86	11.93	22.09	48.32
North Sea	2.84	2.63	3.04	7.73	33.84

Although these figures may not be very accurate, they do confirm the otherwise obvious fact that smaller boats use less netting, and are therefore likely to have lower bycatch rates per day at sea. They also indicate that net lengths used in the Celtic Sea are generally greater than those used in the North Sea.

We have not been able to measure the bycatch rates of porpoises in those fisheries of the Celtic Sea that account for 84% of current fishing effort in terms of days at sea, but if those rates were to be in line with the lowest observed rates elsewhere in the UK, the inshore cod gillnet fishery in the North Sea where rates were measured at 0.0275 porpoises per day at sea (one animal in ~217 hauls with ~6 hauls per day), porpoise bycatches in the rest of the Celtic Sea fisheries would total around another 250 animals per year. This is by no means a robust estimate, but when coupled with what has been observed in the hake fishery indicates that current overall bycatch rates would need to be very low indeed for total porpoise mortalities in the gill and entangling net fisheries of the Celtic Sea to be less than the 200 animals per year proposed as an interim conservation target in the UK's Small Cetacean Bycatch Response Strategy.

1.3. Overview of fishing effort and bycatch rates in UK fisheries: trends through time.

Much of the work under this objective has been undertaken during the drawing up of the UK's Small Cetacean Bycatch Response Strategy, and also in the preparation of reports for ICES and the European Commission (ICES 2002; SEC 2002; SEC 2002) and what is presented here is a brief summary and update of that work.

Pelagic fishing effort is dominated by the herring and mackerel fisheries, which between them have contributed 73% of total pelagic fishing effort since 1997. As discussed above, there are no estimates of cetacean bycatch for any of these fisheries other than the bass fishery, though we have estimated the likely maximum rates in the other fisheries based on the number of hauls with no bycatch that have been observed. The bass fishery effort has been described in more detail in section 1.1.4 above. Overall pelagic effort has been declining slowly in recent years (Figure 5).

Gillnet fisheries have also been declining, at a somewhat faster rate, as shown in Figure 6. The decline has been greatest in the Channel and North Sea. Estimates of porpoise bycatch rates in the North Sea and for the West of Scotland have been used to generate estimates of total bycatch in these two areas for the years 1998 to 2002 in Table 13, following the methodology of previous reports and as described in Northridge and Hammond (1999).

These estimates assume that there is a more or less constant underlying bycatch rate throughout the measurement and extrapolation period. While this is probably a reasonable assumption over a few years, the longer the time period concerned the more likely it is that population level changes, changes in fishing practice, changes in porpoise distribution or foraging behaviour may violate this assumption. The declines in estimates of total catch in Table 13 are driven entirely by declines in fishing effort.

Table 13: Estimates of annual porpoise bycatch: North Sea and West of Scotland.

	North Sea	*Lower 95%*	*Upper 95%*	***West coast***	*Lower 95%*	*Upper 95%*
1998	**609**	477	1017	**101**	74	165
1999	**588**	492	926	**45**	25	68
2000	**531**	463	774	**64**	42	102
2001	**484**	403	718	**43**	32	73
2002	**439**	371	640	**48**	25	68

Figure 5: Trends in Fishing Effort – Pelagic Fisheries

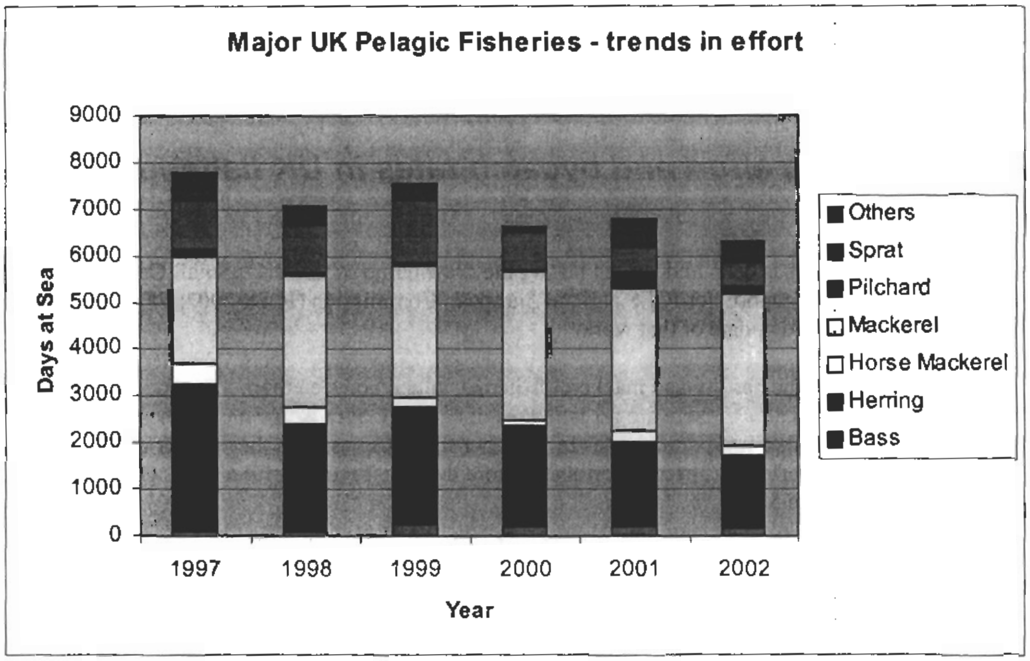
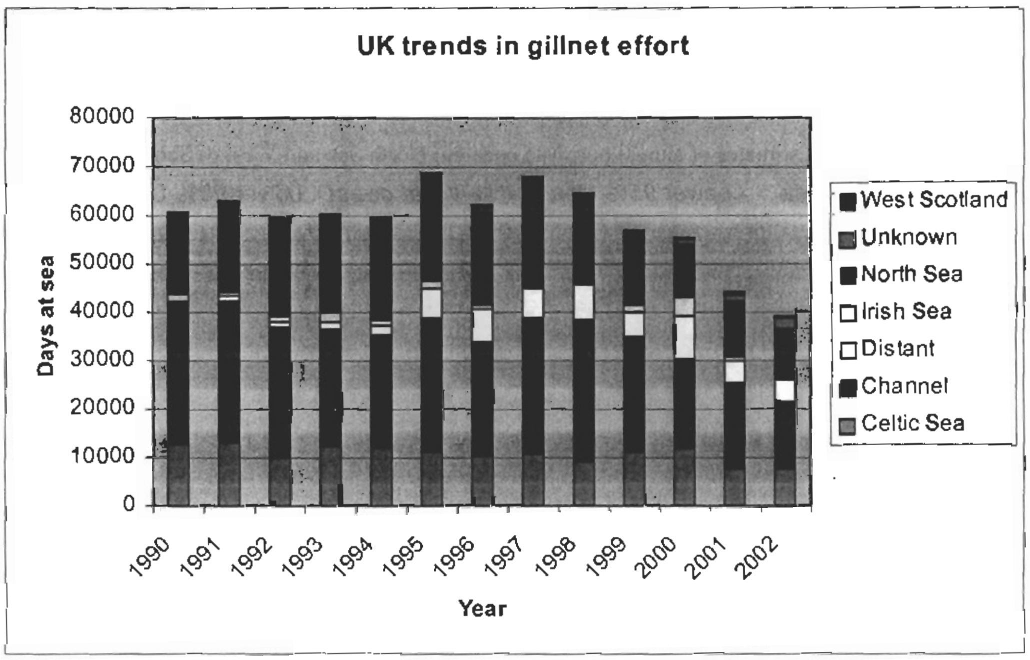


Figure 6: Trends in UK Gillnet Effort 1990-2002 by region



2. *Experimental work examining porpoise bycatches in gillnet fisheries*

Our objectives here were altered part way through the project in agreement with DEFRA, as resources that had been allocated to try to develop a method of tracking porpoises underwater from their clicks were diverted into further practical work to examine the effects of different fishing gear characteristics on porpoise bycatch.

2.1 Gillnet trials: effects of twine type on bycatch rates.

Earlier examination of data recorded by observers in North Sea and West of Scotland gillnet fisheries suggested that porpoise bycatch rates were highest in nets made from multi-monofilament netting. Simple descriptive statistics showed catch rates (porpoises per km.hour of netting soaked) that were an order of magnitude greater in nets made from multi-mono. To test this observation we ran a step-wise generalised linear model with 6 covariates (month, twine type, fishery, depth, longitude, km.hours) with binomially distributed bycatch. The only significant factors associated with the bycatch rate were the twine type and the fishery. It should be noted that the fishery is defined as the target species, and that monofilament and multi-monofilament twines are both used in most of the important fisheries.

This apparent correlation between higher catch rates and the use of multi-monofilament was at first assumed to be because of the expected extra strength of multi-monofilament netting (see later: Figure 7). However, such a correlation does not imply a causal relationship and we therefore tested the presumed effect in a controlled experimental manner. To this end we purchased two sets of skate netting with a 10.5 inch (267mm) stretched mesh size and similar twine diameter, one of which was monofilament nylon (0.6mm diam) and the other was a three strand multi-monofilament. We then chartered an existing gillnet vessel and ran a paired trial of the two types of net, where nets were shot on the same ground, but the order of shooting was randomly determined by a coin toss. Setting both net types in the same area therefore removed any possible area effect. The observer recorded such information as soak time, the target species and main catch, bottom type, fishing characteristics and if there were any bycatch events the numbers of harbour porpoises or seals (both grey seals and common seals)

This experiment was run between August and October 2000. 177 hauls were observed with a total soak time of 9,394 hours. 10 fleets, each with a length of 100 yards (90m) were fished. These consisted of five fleets of monofilament nets and five fleets of multi-monofilament nets. Both sets were hung with a primary hanging ratio of 0.3 and used the same type of floatline. The results are summarized in Table 14.

Table 14: results of experimental trial of mono-filament vs multi-mono

Net Type	No of hauls	No of porpoises	No of porpoises per haul
Multimono	90	5	0.056
Mono	87	5	0.057

The results showed no significant difference in the catch rate of porpoises between the two net types. It must be assumed that the difference found in the observer data was the result of some other undetermined factor for which the twine type was a proxy. This illustrates the importance of not reading too much into analyses of observational data, and particularly the importance of doing trials such as these to test the causal link between any correlations found.

We then ran second experiment in which we chose two extreme types of netting in order to test whether there are any differences at all in the catch rates of porpoises in different net types. To this end we purchased a set of thin twine monofilament nets, with a twine diameter of 0.4mm, and fished this against a new set of 0.6mm twine monofilament nets. Again, both were rigged with a hanging ratio of 0.3, but because we had to rely on what was commercially available, the thin twined net also had a smaller mesh size (90mm stretched mesh).

We were aware that nets are often hauled with large holes, usually attributed by fishermen to the activities of seals. We wished to determine whether any difference in bycatch rate of porpoises might be attributed to animals breaking free of the nets, and we therefore also decided to record the number of large holes in the nets. The second experiment was run between June 2001 and September 2002. 284 hauls were observed with a total soak time of 8,569 hours. Eight fleets, four of thin twine net and four of thick twine net were fished. The thin twine nets were 90 yards (80m) in length and others were 100 yards 990m) in length. The results are summarized in Table 15.

Table 15: Results of experimental trial of thick and thin twined nets.

Net Type	No of hauls	No of porpoises	No of seals	No of porpoises per haul	No of seals per haul
Thin twine	142	1	1	0.00704	0.00704
Thick twine	142	8	10	0.05633	0.07042

There was a clear and significant difference in the bycatch rate of both seals and porpoises between the two net types (χ^2 =6.125 & 8.1; both p <0.01). We assume that this is due to differences in the material used in the net construction, and while we cannot rule out the possibility that the mesh size may have played some role in this difference, a more parsimonious explanation is simply that the thinner twined net is weaker and is more easily broken through by animals such as seals and porpoises.

The number of new holes was counted during each haul (and each was marked at the headrope with a twist of cable to preclude double counting). We did not count small holes where only one or two meshes had been broken, nor did we count rips where the netting had been parted from the leadline. All the nets having been soaked for roughly 1000 hours, there were 39 large holes in the thick twined nets and 58 in the thin twined nets. The difference of 19 holes compares with a difference of 16 seals and porpoises taken in the two types of nets. It would be entirely reasonable therefore to suppose that some if not all of the 'extra' holes in the thin twined nets were caused by seals or porpoises becoming entangled and breaking free or falling out of the net. Of course it may also be true that thinner twined nets are more easily torn on rocks and other obstacles on the sea bed during hauling.

During the third season we tested a new type of netting that has been developed in the USA. This was made from polyamide (nylon) that had been impregnated or 'filled' with barium sulphate. The idea behind this was to increase the density of the material and so increase its acoustic reflectivity. It has been suggested that the primary cause for porpoises getting entangled is a failure to detect the netting and such material might make it easier for them to detect the netting acoustically. Trials in Denmark had shown a lower porpoise bycatch rate in such netting compared with standard nets.

The third trial was run between October 2002 and September 2003. Six fleets of nets each with a total length of 900m were fished according to the same protocol. These nets consisted of 3 fleets of 9.5 inch (241mm) barium sulphate nets with a twine diameter of 0.67mm and 3 fleets of standard skate nets (monofilament, 267mm mesh size, 0.6mm twine diam), each individual net being 90m in length Both nets were hung with the same hanging ratio. The nets were not identical in twine diameter or mesh size, because we had to purchase the barium sulphate netting that was available, and at the time, the 9.5 inch mesh nets were the closest barium sulphate nets to a standard skate net that we could get. 344 hauls were observed with a total soak time of 9,394 hours. The results are summarized in Table 16.

Table 16: Results of trial No 3- testing barium sulphate nets.

Net Type	No of hauls	No of porpoises	No of seals	No of porpoises per haul	No of seals per haul
Barium Sulphate	171	8	10	0.04678	0.05848
Normal nylon	173	3	5	0.01734	0.02890

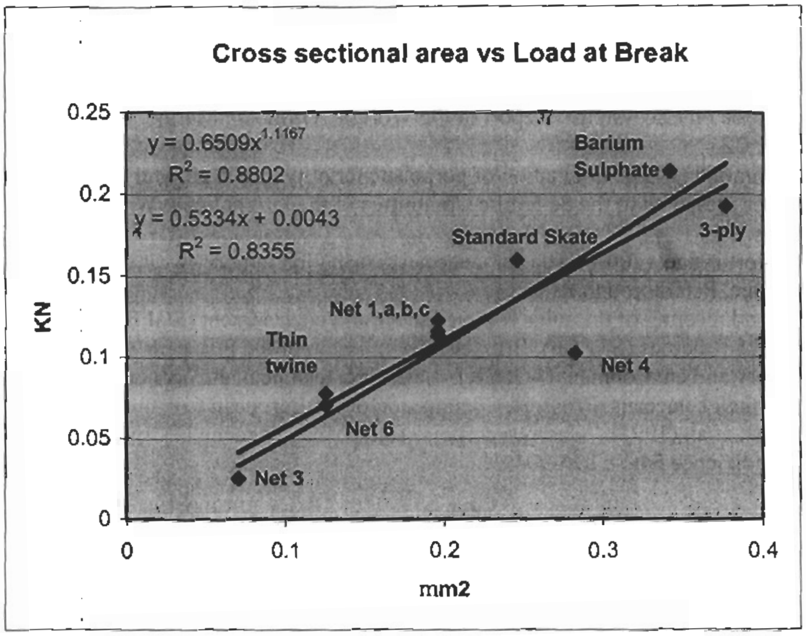
Bycatch rates of both porpoises and seals were higher in the Barium sulphate net than in the normal nets. This difference is significant for porpoises at the 10% level but only at the 20% for seals. The fact that bycatch rates are higher in the barium sulphate nets for both seals and porpoises suggests that there may be a common reason for this, which is not to do with the acoustic properties of the nets. We also measured the number of holes in each net type, and over the course of the trial the barium sulphate nets accumulated 76 large holes, while the normal monofilament nets accumulated 29 more holes at 105. This result is entirely consistent with the results of the second trial and may reflect the increased difficulty for a seal or porpoise to escape with the combined effects of a slight smaller mesh size and a thicker twine, both of which would be expected to increase the amount of force required to break a net.

2.2 Measurements of load at breakage in twines

In order to explore the possibility that porpoises may be able to break free from some nets but not so readily from others, we have begun trials to test net strength using a tensile testing machine in collaboration with Dr Mark Pridham at the Department of Mechanical Engineering at Dundee University. Initial results show that when single meshes are tested, the load at breakage is roughly proportional to the cross sectional area of the twine.

Clearly when several meshes are involved the situation becomes more complex, and we are currently collaborating with Dr Pridham to address the additional complexity of several mesh breakages. These initial results, however, show that the barium sulphate twine was stronger than the standard skate monofilament twine, while the thin twined (0.4mm) twine that we used is only about half as strong as the 0.6mm twine.

Figure 7: Results of some preliminary tests of loads required to break single meshes



2.3 Experimental work using porpoise click detectors.

Under agreement with DEFRA this work has been limited to some trials of T-Pods with a view to determining how easily these could be adapted to determine the bearing of a porpoise click or click train based on differences in the time of arrival. The ultimate objective remains to be able to configure several adjacent hydrophones and click detectors and use them to track the movements of porpoises under water. We have encountered several technical problems with this work.

3. Mitigation work and advice.

Advice to DEFRA, to ICES and the EC on bycatch issues has been provided throughout the duration of this project. Mitigation strategies have been developed with input from SMRU in the UK's small cetacean bycatch response strategy. Numerous short notes and presentations on various aspects of bycatch have been prepared through the course of this project for DEFRA in several forums, including ASCOBANS and the UK's Biodiversity Action Plan Process.

In terms of mitigation, trials of pingers on gillnets were completed under a previous MAFF contract (with major funding from the European Commission) and gillnet mitigation work involving pingers has been limited to input to recent SeaFish led tests of the reliability of currently marketed devices. Experimental trials of nets may lead to developments that could be useful in mitigating porpoise bycatch in gillnets through modification of net construction, but it is too early to speculate on this at present.

Most of our mitigation work has been focussed on attempts to minimise dolphin bycatch in the pelagic pair trawl fishery for bass. The results of this work are provided in Annex 2 and Annex 3 – being reports to DEFRA on additionally funded work, though SMRU staff time for these was covered under the present project.
In summary, we ran a brief test in 2001 using Dukane pingers placed around the mouth of the trawl but observed no effect in terms of reduced bycatch. Subsequently in 2003 we placed several Aquamark pingers around the circumference of two trawls in the rear of the trawl, close to the area where large meshes change to smaller meshes. Again we observed no obvious change in bycatch rate.

Observations of dolphins caught in pelagic trawls suggest that most if not all are found inside the final net section that ends in the cod end. This section is 20-30m long and about 1.8m in circumference, constructed from small mesh (40mm) nylon trawl netting. Dolphins were mostly observed with their beaks poking through these meshes, suggesting they may have been trying to force their way out of the net when they died. In order to keep dolphins out of this part of the net we have developed an exclusion grid in collaboration with Bjornar Isaksen of the Institute of Marine Research in Bergen in Norway. We have used this device for two short trials in 2002 and 2003 and have demonstrated that it does not effect fishing. More importantly, we have had a camera positioned inside the final section of the trawl net pointed at the grid. We expected to see animals finding their way to grid and then, unable to get any further to try to swim upwards and in so doing push open a net trap-door to escape. In fact, although two animals unfortunately drowned whilst apparently trying to escape, dolphins appear to avoid the back end of the trawl (and hence avoid becoming caught) when a grid is in place. We hypothesise that this may be either because they can detect the grid and turn around before reaching it, or because we were also using an acoustic transponder to send data on the grid angle and water flow back to the boat, and that this may have acted as an acoustic deterrent. Whatever the cause, bycatch rates when using the grid system were demonstrably much lower than those in boats fishing alongside without such a system. Mitigation work in this area continues.

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